










Magnetic head.**Publication number:** EP0114076**Publication date:** 1984-07-25**Inventor:** KUMASAKA NORIYUKI; FUJIWARA HIDEO; SAITO NORITOSHI; OTOMO SHIGEKAZU; YAMASHITA TAKEO; KUDO MITSUHIRO**Applicant:** HITACHI LTD (JP)**Classification:****- International:** *G11B5/147; G11B5/31; H01F10/00; H01F10/12; H01F10/13; H01F10/16; G11B5/147; G11B5/31; H01F10/00; H01F10/12; (IPC1-7): H01F10/00; G11B5/16; H01F10/16; H01F10/30***- European:** G11B5/147; G11B5/31D2; H01F10/00**Application number:** EP19840100437 19840117**Priority number(s):** JP19830004270 19830117**Also published as:** US4610935 (A1)
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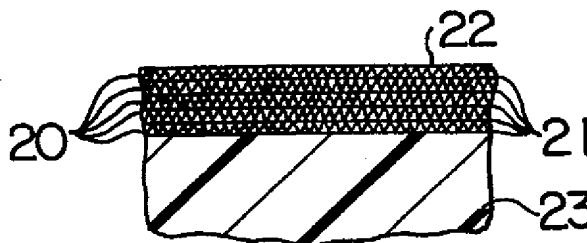
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Magnetic film structure.

A magnetic film structure comprises at least one magnetic film unit (20, 21) wherein a plurality of main magnetic films (20) of 0.05 to 0.5 μm thickness made of a magnetic alloy containing iron or cobalt as principal constituent and having a high saturation magnetic induction of 10,000 gauss or more and a magnetostriction of 10^{-6} or less are laminated through intermediate magnetic films (21) made of a magnetic material such as a nickel and iron alloy or amorphous magnetic alloy different from that of the main magnetic film and being so thin that the influence of coercive force of the intermediate magnetic film (20) does not come out. A plurality of the magnetic film units (20, 21) are also laminated through non-magnetic insulating films (24). The magnetic film structure has high saturation magnetic induction and low coercive force.



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H I T A C H I

Hitachi Ltd.

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MAGNETIC FILM STRUCTURE

1 This invention relates to a magnetic film
structure having high saturation magnetic induction and
low coercive force so as to provide good results when
used for a magnetic head core especially of the type
5 which has performance suitable for high density magnetic
recording.

 With drastic progress in high density magnetic
recording, a metal powder tape has been developed which
can facilitate attainment of a higher coercive force H_c
10 of 1,200 to 1,600 Oe than a coercive force of 600 to
700 Oe of a conventional iron oxide power tape. In order
to obtain satisfactory record on such a high coercive
force recording medium, a magnetic head is required
which is made of a magnetic material having a high
15 saturation magnetic induction. A magnetic material of
an alloy containing iron, cobalt or nickel as principal
constituent can easily be prepared, having a high
saturation magnetic induction of 10,000 gauss or more.

 Conventionally, when preparing a magnetic head
20 or the like by utilizing a metallic magnetic material,
magnetic films are laminated with electrical insulation
therebetween in order to suppress eddy current loss in
high frequency ranges. The laminated magnetic film
structure is prepared by so-called thin film formation
25 technique such as sputtering, vacuum evaporation, ion

1 plating or plating.

Fig. 1 shows a prior art laminated magnetic film structure. This known laminated structure is prepared by alternate and successive formation of magnetic films 10 and non-magnetic insulating films 11 on a non-magnetic insulating substrate 13. Each of the magnetic films 10 has a thickness of several microns and each of the non-magnetic insulating films 11 has a thickness which is about 1/10 of the thickness of the magnetic film 10. However, since the crystalline metallic magnetic film behaves itself like a columnar structure as shown at 12 in Fig. 1, it is difficult for magnetization to move through the boundary of the columnar structure and hence the laminated structure exhibits a large coercive force. In a magnetic head prepared with the magnetic films of such a large coercive force, there arises a problem that a magnetic head core is magnetized when a large external magnetic field is applied thereto.

An approach to this problem is such that magnetic film of a thickness of submicrons and non-magnetic films of about 1,000 Å thickness are alternately laminated to thereby reduce the coercive force. For example, while an about 1 μm thickness single layer film of an alloy of iron and 6.5 weight % silicon (hereinafter, weight % will be simply referred to as %) prepared by sputtering has a coercive force of several oersteds, the laminated structure according to the above proposal can reduce the coercive force to about 1 Oe. A minimum coercive force

1 obtained with this proposed structure will however be
0.8 Oe and for this reason, the proposed structure is
sometimes unsatisfactory for the magnetic head material.

The following references are cited to show the
5 state of the art; Japanese Utility Model Application Laid-
open No. 58613/77 and Japanese Patent Application Laid-open
No. 54408/77.

An object of this invention is to provide a
magnetic film structure having a high saturation magnetic
10 induction and a lower coercive force than that of the
prior art structure.

Another object of this invention is to provide
a magnetic film structure for use in a magnetic head
which can exhibit an excellent recording and reproducing
15 characteristic in relation to a high coercive force
recording medium.

Still another object of this invention is to
provide a laminated magnetic film structure comprised of
laminated magnetic films of high saturation magnetic
20 induction which can exhibit low coercive force and high
permeability.

Specifically, in accordance with teachings of
this invention, crystalline metallic magnetic films having
a high saturation magnetic induction of 10,000 gauss or
25 more are used for easy formation of a magnetic film
structure having a low coercive force which can not be
obtained from the prior art laminated magnetic film
structure in which magnetic films and non-magnetic

1 insulating films are laminated alternately.

The inventors of the present application have found that such a magnetic film structure can be materialized by replacing the non-magnetic insulating
5 intermediate film interposed between adjacent main magnetic films in the prior art laminated magnetic film structure with magnetic intermediate film different from the main magnetic film. Especially, according to the findings, the magnetic intermediate film is preferably made of a
10 magnetic material having a relatively low coercive force (less than 10 Oe) and a low magnetostriction (less than 10^{-6}).

Thus, in the magnetic film structure according to the present invention, a plurality of main magnetic
15 films of a predetermined thickness made of a metallic magnetic alloy having high saturation magnetic induction and low magnetostriction are laminated through intermediate magnetic films of a predetermined thickness made of a magnetic material different from that of the main magnetic
20 films.

Fig. 2 shows, in sectional form, a magnetic film structure according to this invention. As shown, the magnetic film structure comprises main magnetic films
20 made of a magnetic alloy containing, for example, iron or cobalt as principal constituent and having a
25 high saturation magnetic induction, intermediate magnetic films 21 made of an alloy having relatively low coercive force and magnetostriction, for example, a nickel and iron

- 1 alloy (permalloy) or amorphous magnetic alloy, and a
non-magnetic substrate 23.

The intermediate magnetic film 21, when made of
the alloy, is very thin, amounting to 30 to 500 Å and the
5 main magnetic film 20 has such a thickness as not to be
greatly affected by the adverse magnetism of its columnar
crystalline structure 22. Consequently, the columnar
crystalline structure 22 of the main magnetic film 20 can
be sectionalized by the intermediate magnetic film 21.
10 With this magnetic film structure, the magnetization
which is otherwise oriented in a direction vertical to
the film surface along the columnar structure and the
magnetization which is also otherwise difficult to move
through the boundary of the columnar structure are both
15 oriented to the interior of the film so as to have ability
to move within the film under the application of a small
magnetic field, thereby reducing the coercive force. In
addition, the intermediate magnetic films 21 presumably
assist in aiding the magnetic coupling between the
20 respective main magnetic films 20 to enhance the movement
of the magnetization.

Specifically, it is recommended that the main
magnetic film of this invention be made of either a
magnetic alloy containing iron as principal constituent
25 and one or more elements selected from a group
of silicon, aluminum and titanium by 1 to 30% in total
or a magnetic alloy containing cobalt as principal
constituent and one or more elements selected

1 from a group of iron, vanadium, titanium and tin. Either
alloy has a low magnetostriction (less than 10^{-6}) and a
high saturation magnetic induction (more than 10,000
gauss). If the magnetostriction exceeds 10^{-6} , the magnetic
5 characteristic disadvantageously will become increasingly
irregular under the application of stress and if the
saturation magnetic induction is not greater than 10,000
gauss, satisfactory recording on a medium of large
coercive force will disadvantageously be prevented. For
10 the sake of improving corrosion-proof and abrasion-proof
properties and controlling magnetostriction, the alloy
composition of the main magnetic film may be added with
an additive by less than 10%. When the magnetic film
structure is used in a magnetic head associated with a
15 magnetic recording medium having a high coercive force
of 1,200 Oe or more, the main magnetic film preferably
has a saturation magnetic induction of more than 10,000
gauss and a coercive force of less than 10 Oe.

On the other hand, the intermediate magnetic
20 film made of a nickel and iron alloy (permalloy) or
amorphous magnetic alloy preferably has an alloy composi-
tion which exhibits a low coercive force (less than 10 Oe)
and a low magnetostriction (less than 10^{-6}). However,
as far as the magnetic material of the intermediate
25 magnetic film is different from that of the main magnetic
film, namely, the former material contains an element as
principal constituent different from that of the latter
material or has an atomic configuration different from

1 that of the latter material, attainment of effects of the
present invention can be expected. If the same alloy is
used for both the intermediate and main magnetic films,
the columnar structure of the intermediate magnetic film
5 and that of the main magnetic film are linked together
and good results can not be obtained. The amorphous
magnetic alloy is free from this problem and preferably
employed in the present invention.

If the intermediate magnetic film is excessively
10 thick, then the influence of its coercive force becomes
predominant, thus making it difficult to materialize a
laminated magnetic film structure having low coercive
force and high permeability. Accordingly, the thickness
of the intermediate magnetic film is selected to a value
15 which can substantially eliminate the influence of its
coercive force upon the laminated magnetic film structure.
Thus, with the intermediate magnetic film having a low
coercive force (less than 10 Oe) and a thickness of 30
to 500 Å as described above, a fine structure of multi-
20 layer magnetic films can be realized relatively easily.
For example, when a magnetic material having a relatively
high coercive force such as cobalt or nickel is used
for the intermediate magnetic film, it is preferable
that the thickness of the intermediate magnetic film be
25 10 to 80 Å.

As described above, the magnetic film structure
of the present invention preferably has a laminated
structure comprising a plurality of main magnetic films

1 containing iron or cobalt as principal constituent and
having a high saturation magnetic induction, and inter-
mediate magnetic films made of a nickel and iron alloy
or amorphous magnetic alloy and each interposed between
5 adjacent main magnetic films.

The present invention can effectively improve
a crystalline magnetic film structure in which the
magnetic film exhibits the columnar (or needle-like)
structure when it takes the form of a single-layer film.
10 In particular, the coercive force can be reduced by about
one order by applying teachings of the present invention
to a magnetic film structure in which the magnetic film
in the form of a single layer has a coercive force of
the order of several oersteds.

15 Preferably, the thickness of each main magnetic
film ranges from 0.05 μm to 0.5 μm , most preferably, 0.05
 μm to 0.3 μm . For the thickness being less than 0.05 μm ,
the magnetic characteristic of the intermediate magnetic
film comes out and if the intermediate magnetic film is
20 reduced in thickness, film homogeneity will be impaired
to prevent realization of a stable fine structure. For
the thickness being more than 0.5 μm , the influence of
the columnar structure becomes predominant to increase
the coercive force.

25 Preferably, the thickness of each intermediate
magnetic film ranges from 30 \AA to 500 \AA , most preferably,
50 \AA to 300 \AA when the intermediate magnetic film is made
of the nickel and iron alloy or amorphous magnetic alloy,

1 having a coercive force of 10 Oe or less. For the thick-
ness being less than 30 Å, effects of the magnetic
properties of the intermediate magnetic film are diluted
whereas for the thickness being more than 500 Å, the
5 magnetic characteristic of the intermediate magnetic film
is enhanced to increase the coercive force. For the
same reasons, the intermediate magnetic film preferably
has a thickness which ranges from 10 Å to 80 Å, most
preferably, 15 Å to 70 Å when it is made of a material
10 having a relatively high coercive force such as cobalt.
The laminated magnetic film structure of the present
invention wherein the main magnetic films and the inter-
mediate magnetic films are laminated as described
previously can provide a lower coercive force than that
15 of the prior art laminated magnetic film structure wherein
the main magnetic films and the non-magnetic insulating
intermediate films are laminated.

Preferably, the intermediate magnetic film is
made of a nickel and iron alloy having a magnetostriction
20 of 1×10^{-6} or less which contains, for example, about
81% nickel and about 91% iron. When the intermediate
magnetic film is made of an amorphous magnetic alloy, it
is preferable that, for example, cobalt be added
with one or more elements selected from a group of
25 zirconium, titanium, molybdenum, niobium, tungsten,
aluminum, nickel, chromium, silicon and boron or cobalt,
iron and nickel be added with silicon, boron and phosphorus,
respectively, to provide a coercive force of several

1 oersteds or less. The addition of such additives as
above is not limitative. In the case of the amorphous
magnetic alloy, crystallization takes place as the temper-
ature rises beyond a crystallization temperature and the
5 coercive force increases abruptly. As a result, it
happens that the magnetic characteristic of the intermediate
magnetic film comes out to increase the coercive force of
the laminated magnetic film structure to an undesirable
extent. Therefore, the crystallization temperature is
10 desired to be high.

Generally, when the coercive force of the
intermediate magnetic film exceeds 10 Oe, the prepared
laminated magnetic film structure is affected by the
excessive coercive force, making it difficult to obtain a
15 low coercive force.

The number of laminated main magnetic films and
intermediate magnetic films is determined in accordance
with the thickness of the laminated magnetic film structure
adapted for utilization and purpose of the structure and
20 the thus determined number cooperates with the thickness
of each film to provide an intended characteristic.

In accordance with teachings of the present
invention, a thick laminated magnetic film structure
having excellent high frequency magnetic properties can
25 also be materialized by laminating a predetermined number
of laminated magnetic film units of a suitable thickness
each comprised of the main magnetic films and intermediate
magnetic films through non-magnetic insulating films such

1 as SiO_2 films or Al_2O_3 films having electrical insulation.
The number of the laminated films in the laminated
magnetic film unit and the number of the laminated magnetic
film units in the thick laminated magnetic film structure
5 are determined in accordance with the thickness of the
thick laminated magnetic film structure adapted for
utilization and purpose of the structure and the thus
determined number cooperates with the thickness of the
main magnetic film, intermediate magnetic film and non-
10 magnetic insulating film to provide an intended characteristic.

The non-magnetic insulating film normally has a
thickness which ranges from $0.05 \mu\text{m}$ to $1 \mu\text{m}$. For the
thickness being more than $1 \mu\text{m}$, the magnetic properties
15 such as permeability are degraded whereas for the thickness
being less than $0.05 \mu\text{m}$, the formation of a complete
film becomes difficult, resulting in insufficient inter-
layer insulation.

Each of the laminated magnetic film units to
20 be laminated through the non-magnetic insulating films
normally has 10 to 50 main magnetic films which are
laminated through the intermediate magnetic films.
Preferably, about 30 main magnetic films are used to
obtain a thick laminated magnetic film structure having
25 excellent high frequency magnetic properties.

The present invention will be apparent from the
following detailed description taken in conjunction with
the accompanying drawings, in which:

1 Fig. 1 is a sectional view showing a prior art
laminated magnetic film structure;

 Fig. 2 is a sectional view showing a typical
example of a laminated magnetic film structure according
5 to the invention;

 Fig. 3 is a schematic diagram showing a
sputtering device used for preparation of a magnetic film
structure according to an embodiment of the invention;

 Figs. 4 and 5 are graphs showing magnetic
10 characteristics of a laminated magnetic film structure
embodying the invention which comprises main magnetic
films made of an iron and 6.5% silicon alloy and inter-
mediate magnetic films or spacers of permalloy;

 Fig. 6 is a sectional view showing another
15 embodiment of the laminated magnetic film structure;

 Figs. 7, 8a and 8b are diagrams useful in
explaining a magnetic head incorporating the laminated
magnetic film structure; and

 Figs. 9a and 9b fragmentary enlarged views showing
20 the magnetic film structure near a magnetic gap of a
magnetic head to explain effects of the present invention
as applied to a magnetic recording thin film head, the
former illustrating a case according to the prior art
and the latter illustrating a case according to an embodi-
25 ment of the present invention.

 The invention will now be described by way of
example.

 An RF sputtering apparatus as shown in Fig. 3 is

1 used for preparing the magnetic film structure. Three
independent sets of opposing electrodes are provided
inside a vacuum container 30. Electrodes 31, 32 and 33
are target electrodes (cathodes). An alloy target
5 containing iron or cobalt as principal constituent for
formation of the main magnetic film is disposed on the
electrode 31, an alloy target made of an nickel and iron
alloy (permalloy) or amorphous magnetic alloy for formation
of the intermediate magnetic film is disposed on the
10 electrode 32, and a target made of an insulating material
such as SiO_2 or Al_2O_3 for formation of the non-magnetic
insulating film is disposed on the electrode 33. Electrodes
34, 35 and 36 respectively provided directly beneath the
electrodes 31, 32 and 33 are substrate electrodes (anodes).
15 A specimen 37 may be carried on any one of the substrate
electrodes as necessary. Also, if necessary, a magnetic
field may be applied in parallel to the surface of the
specimen 37 by means of electromagnets 38 and 38' during
sputtering so that the direction of easy magnetization of
20 the magnetic film structure to be formed may be oriented
in parallel to the surface of the film. Electric
discharge is effected within an atmosphere of argon gas
which is introduced into the vacuum container 30 via a
gas inlet pipe 39. An evacuation pipe 40 is provided for
25 the vacuum container 30, and a switch 41 is adapted to
switch the electrodes.

1 EXAMPLE 1

Preparation of an iron and 6.5% silicon film standing for the main magnetic film will first be described.

The following are various condition selected
5 for sputtering under a relatively good condition.

Target composition iron and 7.5% silicon

RF power density 2.8 W/cm^2

Argon pressure 2×10^{-2} Torr

Substrate temperature 350°C

Anode-cathode separation
distance (representing
hereinafter the distance between
target electrode and substrate
electrode) 25 mm

Film thickness $1.5 \mu\text{m}$ (for reference)

$0.1 \mu\text{m}$ (this example)

A single layer film of $1.5 \mu\text{m}$ thickness thus formed on the non-magnetic substrate has magnetic properties including a coercive force H_c of 2.5 Oe, a permeability μ of 400 at 5 MHz, and a saturation magnetic induction
10 of 18,500 gauss. Sputtering is effected under the application of a magnetic field (about 10 Oe) oriented in one direction parallel to the surface of the magnetic film. These magnetic properties are measured in the direction of hard magnetization which is vertical to the
15 surface of the magnetic film. A glass substrate is used as the non-magnetic substrate. Of various conditions for sputtering, the silicon content in the target must be excessive since the composition in a resulting sputtered

1 film tends to shift to the iron content in comparison
with the composition in the target. As the RF power
density increases beyond 2 W/cm^2 , the coercive force H_c
tends to decrease. The substrate temperature is preferably
5 above 250°C to mitigate stress in the film. As the
anode-cathode separation distance decreases, the coercive
force tends to become low but in consideration of stability
of electric discharge during sputtering, the distance is
preferably about 20 to 30 mm. Preferably, the vacuum
10 container is highly evacuated to a vacuum degree of the
order of 10^{-7} Torr prior to the introduction of argon
gas since the remaining oxygen and impurity will adversely
affect the magnetic properties of the magnetic film
structure.

15 Typically, the intermediate magnetic film is
prepared by RF sputtering under the following conditions.

Target material	.....	83% nickel and 17% iron
RF power density	.....	0.5 W/cm^2
Argon pressure	.....	5×10^{-3} Torr
Substrate temperature	....	250°C
Anode-cathode separation distance	.....	50 mm
Film thickness	.....	100 \AA

A thus prepared intermediate magnetic film
approximately has a composition of 81% nickel and 19% iron.
A laminated magnetic film structure having 15 laminated
20 main magnetic films is thus prepared, having a total

- 1 thickness of about $1.5 \mu\text{m}$ with each of the main magnetic films formed in $0.1 \mu\text{m}$ thickness and each of the intermediate magnetic films formed in 100 \AA thickness.

- Another intermediate magnetic film is prepared
5 by using an amorphous magnetic alloy under the following conditions.

Target material	.....	$\text{Co}_{80} \text{Mo}_{9.5} \text{Zr}_{10.5}$,
		$\text{Co}_{82} \text{Nb}_{13} \text{Zr}_5$,
		$\text{Co}_{59} \text{W}_5 \text{Zr}_6$,
		$\text{Co}_{81} \text{Ti}_{19}$
RF power density	.....	0.8 W/cm^2
Argon pressure	.....	$5 \times 10^{-3} \text{ Torr}$
Substrate temperature	.....	150°C
Anode-cathode separation distance	.....	50 mm
Film thickness	.....	100 \AA

For reference, an intermediate magnetic film of SiO_2 or molybdenum is also prepared.

- When preparing the intermediate magnetic film
10 by using the amorphous magnetic alloy, the substrate temperature is set to 250°C during sputtering of the main magnetic films.

- Table 1 shows magnetic properties of the laminated magnetic film structure having the thus prepared
15 main magnetic films of iron and 6.5% silicon alloy and various kinds of intermediate magnetic films as listed in Table 1. Magnetic properties of a plurality of

1 structures immediately after sputtering are averaged and
indicated in Table 1. Item (a) represents properties of
single layer films of iron and 6.5% silicon alloy, items
(b) and (c) represent properties of laminated magnetic
5 film structures having the prior art non-magnetic
insulating intermediate films, and items (d) to (h)
represent properties of laminated magnetic film struc-
tures having intermediate magnetic films of permalloy or
amorphous magnetic alloy according to teachings of the
10 present invention. As will be seen from the results shown
in Table 1, the laminated magnetic film structures having
the intermediate magnetic films according to the invention
have an extremely lower coercive force than that of the
prior art laminated magnetic film structures having the
15 non-magnetic insulating intermediate films. Specifically,
according to the present invention, the coercive force
is reduced to below 0.5 Oe to provide a practically
significant permeability.

Table 1

Magnetic properties Film structure		Coercive force Hc (Oe)	Permeability μ (at 5 MHz)	Saturation magnetic induction Bs (G)
Intermediate films of laminated structure	(a) Single layer film	2.5	400	18,500
	Non-magnetic material	(b) SiO ₂	1.0	18,000
		(c) Mo	0.9	18,000
		(d) Ni-19% Fe	0.4	18,000
		(e) Co ₈₀ -Mo _{9.5} -Zr _{10.5}	0.4	17,000
	Amorphous magnetic alloy	(f) Co ₈₂ -Nb ₁₃ -Zr ₅	0.45	18,000
		(g) Co ₈₉ -W ₅ -Zr ₆	0.5	18,500
		(h) Co ₈₁ -Ti ₁₉	0.4	17,000

* 17 0 1 0 *

1 According to the present invention, each of the
main magnetic films can have a thickness which ranges
from 0.05 μm to 0.5 μm to ensure that the columnar struc-
ture can be sectionalized to an extent that the magnetic
5 properties of the laminated magnetic film structure
are not affected adversely.

Fig. 4 shows the relation between the thickness
of the intermediate film or spacer, coercive force H_c
and permeability μ at 5 MHz when the main magnetic film
10 of iron and 6.5% silicon alloy has a thickness of 0.1 μm
and the intermediate magnetic film is made of permalloy.
The laminated magnetic film structure has 15 main
magnetic films and the intermediate magnetic films
interposed between adjacent main magnetic films. It will
15 be seen from Fig. 4 that the coercive force is about 0.8 Oe
for the thickness of the intermediate magnetic film which
ranges from 30 \AA to 500 \AA , is less than 0.5 Oe for the
thickness range of 50 to 300 \AA and is minimum near 100 \AA .
The permeability, on the other hand, becomes maximum
20 near 100 \AA . Although the influence of the thickness of
the intermediate magnetic film slightly differs depending
on the type of material of the intermediate magnetic
film and the thickness of each of the main magnetic
films, the range for preferable coercive force substantially
25 coincides with the range for preferable permeability.
For the thickness being less than 30 \AA , the magnetic
properties of the intermediate magnetic film are diluted
to increase the coercive force whereas for the thickness

1 being less than 10 \AA , it is difficult to block the
columnar structure in the main magnetic film, allowing
the columnar structure to grow, whereby the effects of
the present invention are degraded.

5 For the thickness of the intermediate magnetic
film being more than 500 \AA , on the other hand, the
magnetic properties of the intermediate magnetic film
comes out to increase the coercive force and decrease
the saturation magnetic induction of the main magnetic
10 film even when the main magnetic film inherently has a
high saturation magnetic induction. Since the thickness
of the intermediate magnetic film is difficult to directly
measure, it is calculated from theoretical sputtering
rate when the alloy is deposited to a thickness of
15 several microns and controlled in terms of time.

Because of the coercive force of the inter-
mediate magnetic film being less than 10 Oe in this example,
the thickness can be set to a range which is relatively
easy to control, bringing out significant, practical
20 effects.

In this example, a magnetic field is applied in
one direction parallel to the surface of the main magnetic
film during sputtering so that the direction of easy
magnetization is established which coincides with the
25 direction of the applied magnetic field. As shown in
Fig. 5, when the frequency of magnetic field is varied,
the permeability (represented by curve 51) is measured
in the direction of the applied magnetic field (direction

1 of easy magnetization) and the permeability (represented
by curve 52) is measured in the direction vertical to the
applied magnetic field (direction of hard magnetization).
It will be seen that the latter permeability is higher
5 than the former. Accordingly, in a magnetic head
incorporating the laminated magnetic film structure of
the present invention, its direction of hard magnetization
can be arranged in an advantageous direction with
respect to a magnetic circuit for the magnetic head.

10 EXAMPLE 2

Another example of the present invention will
be described hereunder.

For example, when sputtering a target of cobalt
and 12% iron alloy under the following conditions to
15 prepare a laminated magnetic film structure having main
magnetic films of cobalt and 12% iron alloy, a resulting
single layer structure exhibits a coercive force of
several of tens of oersteds whereas a resulting structure
according to the present invention exhibits a coercive
20 force which is reduced to 1 Oe or less. Since the cobalt
and iron alloy inherently has a high coercive force,
the film thickness needs to be reduced slightly.

Target composition	.....	Co - 12% Fe
RF power density	.....	2.5 W/cm ²
Argon pressure	.....	1 x 10 ⁻³ Torr
Substrate temperature	.....	150°C

Anode-cathode separation distance	30 mm
Thickness of Co-Fe alloy film	0.05 μ m
Composition of intermediate film	Co ₈₀ Mo ₁₀ Zr ₁₀
Thickness of intermediate film	80 Å
The number of laminated Co-Fe alloy films	10
The number of intermediate films	9
Coercive force Hc of laminated magnetic film structure	1 Oe
Saturation magnetic induction of laminated magnetic film structure	15,000 gauss

1 Similar results can be obtained with intermediate magnetic films of permalloy. Sputtering conditions for the intermediate magnetic film are the same as those in Example 1.

5 The foregoing Examples 1 and 2 clearly indicate that satisfactory effects can be attained whenever the main magnetic film used in the present invention is made of the magnetic alloy which contains iron or cobalt as principal constituent and has a high saturation magnetic

10 induction (more than 10,000 gauss) and a magnetostriction of nearly zero. Especially, in a magnetic film structure wherein the magnetic film prepared by thin film formation technique exhibits a columnar structure which is vertical or oblique to the film surface, the present invention

15 can reduce the coercive force, thereby providing a

- 1 laminated magnetic film structure suitable for use in
a magnetic head.

EXAMPLE 3

Fig. 6 shows still another example of the film
5 structure according to the present invention which is a
thick laminated magnetic film structure. In this example,
a plurality of laminated magnetic film units (prepared
in accordance with Examples 1 and 2) each comprised of
alternate lamination of main magnetic films 20 and
10 intermediate magnetic films 21 and having a thickness of
about 5 microns are laminated on a non-magnetic substrate
23 through second intermediate films of 0.1 μm thickness
made of a non-magnetic insulating material such as SiO_2
or Al_2O_3 . The thus prepared thick laminated magnetic
15 film structure is free from degradation of permeability
in high frequency ranges, thus providing an excellent
magnetic head core. In particular, this thick laminated
magnetic film structure can be used in a video head
having a track width of 10 μm or more.

20 Fig. 7 shows a magnetic head in which two thick
laminated magnetic film structures formed on respective
non-magnetic substrates and machined into a predetermined
configuration are mated together so that magnetic gap
surfaces oppose to each other. A magnetic film structure
25 62 is formed on a first non-magnetic substrate 61, and a
second non-magnetic substrate 63 adapted to protect the
magnetic film structure is bonded by glass, for example,

1 to the first substrate or the magnetic film structure.
Denoted by 64 is a magnetic gap and 65 is a window for
coil winding. In this example, the thickness of the
laminated magnetic film structure 62 corresponds to the
5 track width.

Figs. 8a and 8b show a magnetic recording
thin film head incorporating the laminated magnetic film
structure according to the invention, where Fig. 8a
illustrates a sectional view of a magnetic head core and
10 Fig. 8b a top view thereof. In Figs. 8a and 8b, there
are illustrated a non-magnetic substrate 71, a lower
magnetic film structure, an upper magnetic film structure,
a conductor coil 74 and a magnetic gap 75. In this
example, the thickness of the magnetic film structure
15 being less than several microns suffices and the non-
magnetic insulating film 24 as required for the Fig. 6
example can be dispensed with.

Other effects brought about by the present
invention will now be described with reference to Figs. 9a
20 and 9b which illustrate, in fragmentary enlarged form,
a portion of the magnetic film structure near the
magnetic gap of the magnetic head shown in Figs. 8a and
8b. More particularly, illustrated in Fig. 9a are
magnetic film structures 72 and 73 which are constituted
25 by a single-layer film having a large columnar structure
according to the prior art. In this case, the columnar
structure is disturbed at bent portions 76 and 77, causing
cracks or corrosion thereat. In addition, stress is

Patented May 17, 1966

- 1 concentrated at the bent portions to create cracks thereat.
In contrast thereto, in the case of the magnetic head
incorporating the laminated magnetic film structures
according to the present invention, the crystalline struc-
5 ture is fine and uniformly continuous at the bent portions
as shown in Fig. 9b, so that stress concentration at the
bent portions can be reduced to suppress the creation
of cracks, thereby ensuring provision of a highly
corrosion-proof magnetic circuit.
- 10 Obviously, many modifications and variations
of the present invention are possible in the light of
the above teachings. It is therefore to be understood
that within the scope of the appended claims, the
invention may be practiced otherwise than as specifically
15 described.

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Patented May 11, 1966

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CLAIMS:

1. A magnetic film structure comprising at least one laminated magnetic film unit (20,21) wherein a plurality of main magnetic films (20) of a predetermined thickness made of a metallic magnetic alloy having high saturation magnetic induction and low magnetostriction are laminated through intermediate magnetic films (21) of a predetermined thickness made of a magnetic material different from that of said main magnetic films.
2. A magnetic film structure according to Claim 1, wherein said main magnetic film (20) is an alloy film having a saturation magnetic induction of 10,000 gauss or more and a magnetostriction of 10^{-6} or less.
3. A magnetic film structure according to Claim 1 or 2 wherein said main magnetic film (20) is an alloy film of a composition containing iron or cobalt as principal constituent.
4. A magnetic film structure according to Claim 1, 2 or 3 wherein each of said main magnetic films (20) has a thickness which ranges from 0.05 μm to 0.5 μm .
5. A magnetic film structure according to Claim 1, 2, 3 or 4 wherein said intermediate magnetic film (21) is an alloy film having a coercive force of 10 oersted or less and a magnetostriction of 10^{-6} or less.
6. A magnetic film structure according to Claim 5 wherein said intermediate magnetic film (21) is made of an nickel and iron alloy or amorphous magnetic alloy.

7. A magnetic film structure according to Claim 5 or 6 wherein each of said intermediate magnetic films (21) has a thickness which ranges from 30 Å to 500 Å.
8. A magnetic film structure according to Claim 1, 2, 3, 4, 5, 6 or 7 wherein said main magnetic film (20) has a coercive force of 10 oersted or less.
9. A magnetic film structure according to Claim any one of Claims 1 to 8 wherein a plurality of the laminated magnetic film units (20, 21) are laminated through non-magnetic insulating films (24).
10. A magnetic film structure according to Claim 9 wherein said non-magnetic insulating film (24) has a thickness of 0.05 to 1 μm .
11. A magnetic film structure according to Claim 10 wherein said non-magnetic insulating film (24) is made of oxide of metal or semiconductor element.
12. A magnetic film structure according to Claim 11 wherein said non-magnetic insulating film (24) is made of silicon oxide or aluminum oxide.

FIG. 1 PRIOR ART

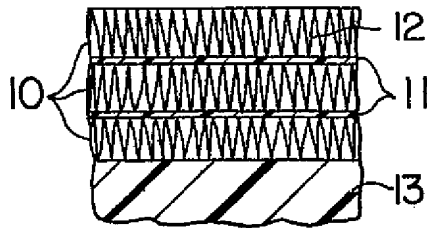


FIG. 2

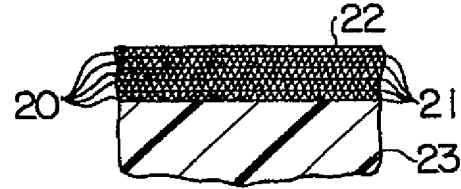


FIG. 3

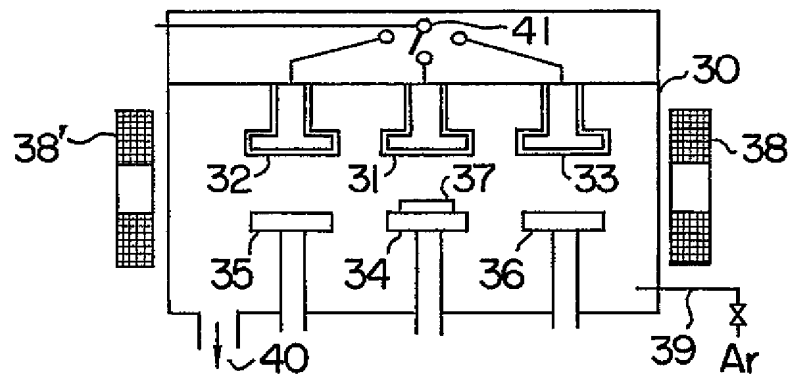


FIG. 4

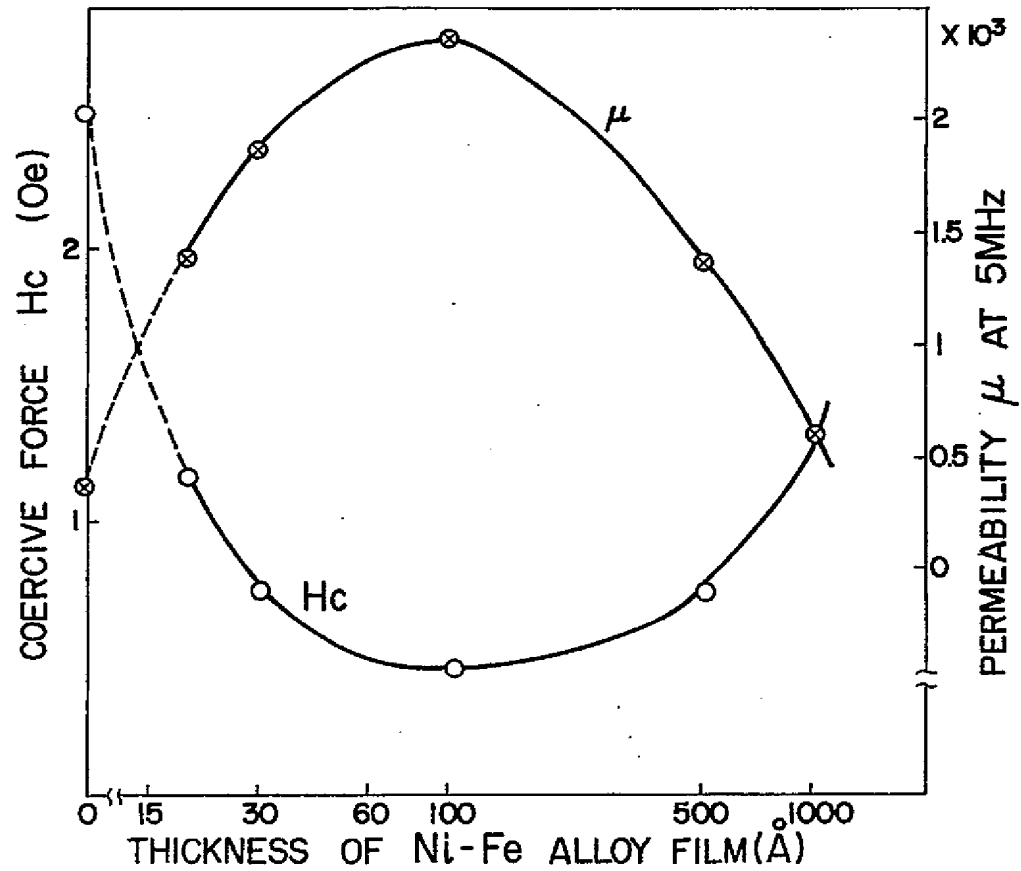


FIG. 5

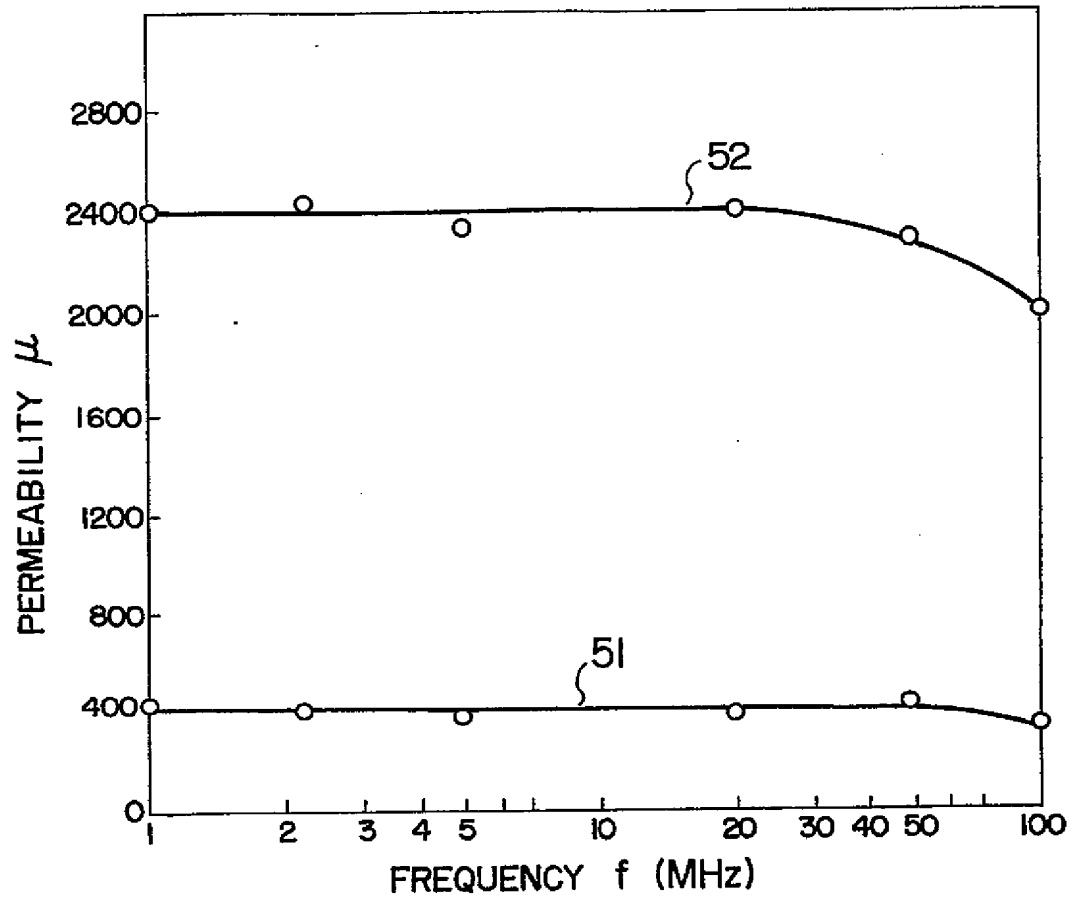


FIG. 6



FIG. 7

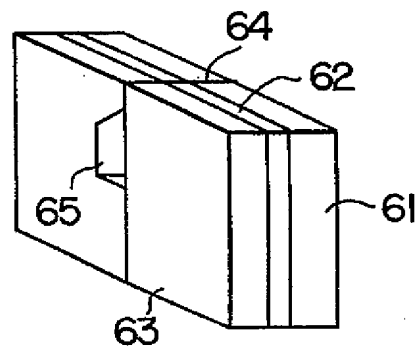


FIG. 8a

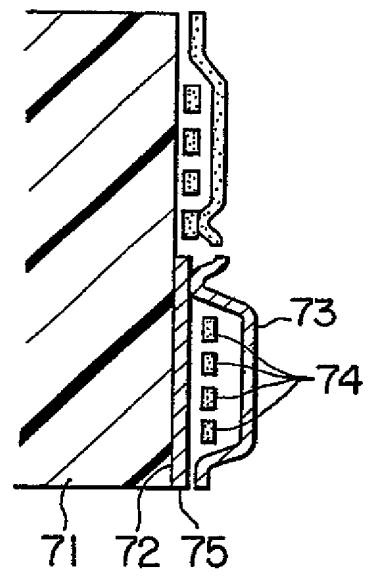


FIG. 8b

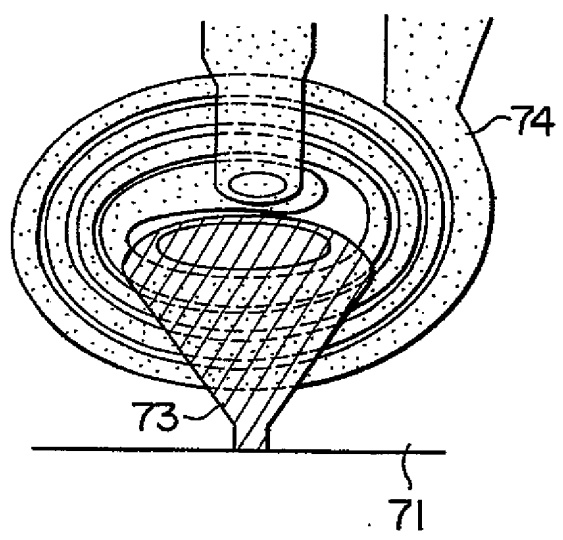


FIG. 9a

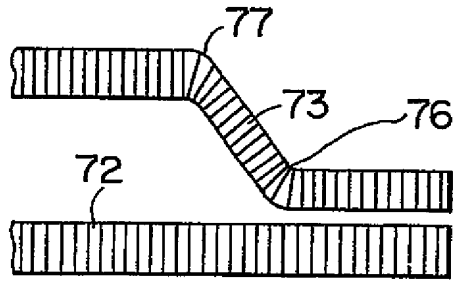


FIG. 9b

